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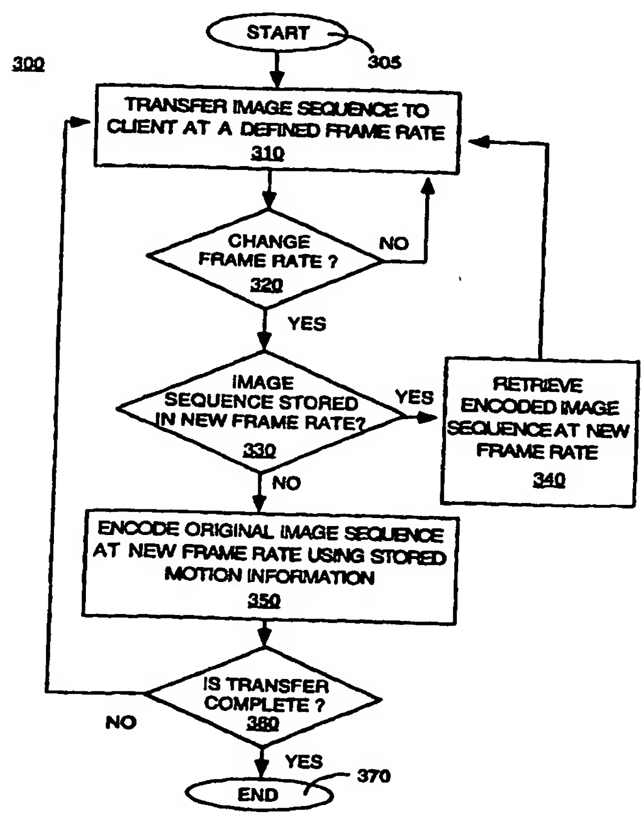
(54) Title: APPARATUS AND METHOD FOR DYNAMICALLY CONTROLLING THE FRAME RATE OF VIDEO STREAMS

(57) Abstract

An apparatus and method for dynamically varying the frame rate of an image sequence is disclosed. In one embodiment, the image sequence is encoded and stored at different frame rates (e.g., 30, 25, 20 fps and so on). Alternatively, only the motion information , e.g., motion vectors, for the other frame rates are stored.



APPARATUS AND METHOD FOR DYNAMICALLY CONTROLLING THE FRAME RATE OF VIDEO STREAMS

This application claims the benefit of U.S. Provisional Application No. 60/090,814 filed on June 26, 1998, which is herein incorporated by reference.

The invention relates generally to the field of digital multimedia communications over a network, e.g., computer networks. More specifically, the invention relates to a method of storing motion information for a sequence of images in different frame rates to effect dynamic frame rate control over a network.

BACKGROUND OF THE DISCLOSURE

The increasing demand for digital video/audio information presents an ever increasing problem of transmitting and/or storing an enormous amount of information. For example, the growth of the Internet and the proliferation of Internet browsers in recent years has enabled millions of users to access various information in a matter of seconds. Most of the information is currently in the form of text and/or still images and graphics. Generally, this type of information can be quickly downloaded and displayed by a user. More recently, audio and video clips or sequences have been added to numerous webs sites. Without an increase in bandwidth, accessing these clips requires more computational cycles and access time due to the sheer size of the image sequences.

Two methods of accessing an image sequence across a network are available. First, the user can download the compressed bitstream in its entirety, and then decode and display the image sequence locally using the user's computer. One drawback of this method is the length of time that a user must wait while the image sequence is being downloaded. Another drawback is that the user may need to reserve a large storage space to accommodate a large image sequence.

at different frame rates (e.g., 30, 15, 10 and 5 fps). This embodiment increases the storage requirement for a server.

In a second embodiment, only the motion information, e.g., motion vectors, for the other frame rates are stored. Namely, the image sequence is first encoded and stored at a preferred frame rate and then the same image sequence is encoded at one or more different frame rates. The encoding process at other frame rates can be performed off-line. However, only the motion information is saved and stored, e.g., in "motion files", for the other frame rates, thereby reducing the storage requirement of the server. Thus, when it is necessary to re-encode the image sequence to accommodate a different frame rate, motion vectors are obtained from a storage device, instead of being computed. This method enables the image sequence to be re-encoded at a different frame-rate in real-time. Additionally, the motion files are significantly smaller than the corresponding compressed image sequence.

BRIEF DESCRIPTION OF THE DRAWINGS

The teachings of the present invention can be readily understood by considering the following detailed description in conjunction with the accompanying drawings, in which:

FIG. 1 illustrates a block diagram of a network environment having a server incorporating the dynamic frame rate control of the present invention;

FIG. 2 illustrates a block diagram of an encoder incorporating the dynamic frame rate control of the present invention;

FIG. 3 illustrates a flowchart of a method for effecting the dynamic frame rate control;

FIG. 4 illustrates a block diagram of a motion file of the present invention; and

FIG. 5 illustrates a block diagram of an encoding system of the present invention.

server 110 having an encoder 112, a decoder 114 and a storage 116. The encoder 112 is an encoder capable of performing motion estimation and retrieving motion information. As such, the encoder 112 can be implemented as an MPEG or H.263 compliant encoder.

In operation, one or more image sequences are pre-encoded and stored in storage 116 at a particular bit rate and frame rate. If a client 130 requests an image sequence from the server 110 that matches the bit rate and frame rate of the pre-recorded image sequence, then the server will simply forward the image sequence directly to the client via the network without further processing.

If the client requests an image sequence at a different frame rate from the frame rate in which the image sequence was encoded, then the server 110 must decode the encoded image sequence using the decoder 114. It should be noted that if the original image sequence is also stored in the server 110, then the decoding operation and the decoder 114 itself can be omitted all together, since the original image sequence is readily available.

Once the original image sequence is obtained (either through decoding the encoded image sequence or retrieving the original image sequence from storage), the encoder 112 can now re-encode the image sequence at the new frame rate. However, the encoder 112 does not have to compute the motion information from the image sequence. Instead, the encoder 112 reads the motion information from a "motion file" associated with the new frame rate, e.g., 25 fps, 20 fps, 15 fps, 10 fps, 5 fps and so on. Since the majority of the computational cycles in an encoding process is spent in generating motion information, e.g., motion vectors, encoder 112 can now quickly re-encode the image sequence in real-time using the stored motion information to accommodate a frame rate as requested by a client.

Effectively, a second knob is provided to a client for varying the frame rate of the image sequence. By reducing the frame-rate of the image sequence, the bandwidth will be reduced without further loss in the spatial quality (temporal quality would be reduced instead). The present dynamic

of information that is transmitted on a channel because only the changes between the current and reference frames are coded and transmitted.

Alternatively, the present invention incorporates a storage 116 for storing motion files for an image sequence at various frame rates. Namely, if the current image sequence on path 210 has been previously encoded and the motion information for the image sequence is stored in storage 116, then the motion estimation process performed by the motion estimation module 240 is bypassed and the associated motion vectors for a particular frame rate are simply read from a motion file stored in storage 116. This process greatly increases the speed with which the image sequence is encoded. However, if the image sequence was not previously encoded or the motion information for a desired frame rate was not previously generated, then the motion vectors are generated using motion estimation module 240. The resulting motion vectors can then be stored in a new motion file in storage 116.

The motion vectors from the motion estimation module 240 or the storage 116 are received by the motion compensation module 250 for improving the efficiency of the prediction of sample values. Motion compensation involves a prediction that uses motion vectors to provide offsets into the past and/or future reference frames containing previously decoded sample values that are used to form the prediction error.

Furthermore, prior to performing motion compensation prediction for a given macroblock, a coding mode must be selected. In the area of coding mode decision, MPEG provides a plurality of different macroblock coding modes. Specifically, MPEG-2 provides macroblock coding modes which include intra mode, no motion compensation mode (No MC), frame/field/dual-prime motion compensation inter mode, forward/backward/average inter mode and field/frame DCT mode.

Once a coding mode is selected, motion compensation module 250 generates a motion compensated prediction (predicted image) on path 252 of the contents of the block based on past and/or future reference pictures. This motion compensated prediction on path 252 is subtracted via

back to the prediction signal from the motion compensation module via summer 255 to produce a decoded reference picture (reconstructed image).

FIG. 3 illustrates a flowchart of a method 300 for effecting the dynamic frame rate control of the present invention. More specifically, FIG. 3 illustrates a method for allowing a client to dynamically change the frame rate of an image sequence.

Method 300 starts in step 305 and proceeds to step 310, where an image sequence is transferred to a client at a predefined frame rate. It should be noted that if the frame rate requested by the client does not match the frame rate of the pre-recorded image sequence, then step 310 is bypassed and method 300 proceeds to step 320.

In step 320, method 300 queries whether the frame rate is changed. The frame rate of an image sequence can be changed for a number of different reasons, e.g., as requested by the client, or the bandwidth of the communication channel has changed and is detected by the server. If the query is negatively answered, then method 310 returns to step 310 and continues sending the image sequence to the client at a predefined frame rate. If the query is affirmatively answered, then method 300 proceeds to step 330.

In step 330, method 300 queries whether the image sequence is stored in the desired new frame rate. Namely, method 300 is inquiring whether there is a stored image sequence that was previously encoded at the desired frame rate.

In one embodiment of the present invention, each image sequence is encoded at a plurality of different frame rates (stored information). For example, an original image sequence can be encoded in three different frame rates, such as 30 fps, 25 fps and 20 fps. If the frame rate is changed from 30 fps to 25 fps, the server simply reads the image sequence from a different file. However, this embodiment dictates a large storage requirement for the server.

Returning to step 330, if the query is affirmatively answered, then method 300 proceeds to step 340, where the stored encoded image sequence

More specifically, the presence of motion information field 420 is implemented as a single bit per macroblock. A zero ("0") indicates that there are no motion vectors associated with a current MB (which would be the case if the MB is not encoded (COD = 1) or if it is encoded in INTRA mode). A one ('1') indicates that there is one motion vector for the current macroblock, where the motion vector is stored in the motion information field 440.

Optionally, the mode information field 430 is provided to further distinguish between the COD = 1 case, and the INTRA mode. Namely, if the encoder is informed that no motion information is available for a current block, then the encoder must determine whether the absence of motion information is due to the lack of motion in the current block or the macroblock is being Intra coded. Generally, an encoder will perform a Sum of Absolute Difference (SAD) calculation when no motion vector is available for the purpose of determining whether the MB should be INTRA coded. Namely, the absolute difference between each corresponding pixel value, e.g., within an area such as a macroblock between successive frames is performed. Next, a sum of the all the absolute difference values is compared to a predicted SAD, which serves as a threshold to measure the degree of change in the macroblock. The Mode Decision is then selected accordingly, i.e., Intra coding for substantial change and Inter coding for insubstantial change.
Unfortunately, these SAD calculations are time consuming and will affect the performance of the real-time encoder.

As such, the mode information field 430 provides an additional bit such that the combination of the presence of motion information field and the mode information field allows the implementation of a variable length code (one or two bits) in the motion file that can be used to indicate both the COD and the MB type (Intra or no motion). For example, a '0' would indicate COD = 1, a '10' would indicate mode = INTRA and a '11' would indicate mode = INTER and presence of a motion vector. The implementation of the reason for absence of motion information field 430

computer 510. The encoder 516 and the decoder 518 can be physical devices which are coupled to the CPU 512 through a communication channel. Alternatively, the encoder 516 and the decoder 518 can be represented by a software application (or a combination of software and hardware, e.g., application specific integrated circuits (ASIC)) which is loaded from a storage device and resides in the memory 512 of the computer. As such, the encoder 200 of the present invention can be stored on a computer readable medium, e.g., a memory or storage device. In turn, the motion information, i.e., motion files and the encoded image sequence at various frame rates, which are generated by the encoder 516, can also be stored on a computer readable medium, e.g., RAM memory, magnetic or optical drive or diskette and the like.

The computer 510 can be coupled to a plurality of input and output devices 520, such as a keyboard, a mouse, a camera, a camcorder, a video monitor, any number of imaging devices or storage devices, including but not limited to, a tape drive, a floppy drive, a hard disk drive or a compact disk drive. The input devices serve to provide inputs to the computer for producing the encoded video bitstreams or to receive the sequence of video images from a storage device or an imaging device.

Although various embodiments which incorporate the teachings of the present invention have been shown and described in detail herein, those skilled in the art can readily devise many other varied embodiments that still incorporate these teachings.

6. A data structure stored on a computer readable medium comprising:
a start of frame code field; and
motion information field.

7. The data structure of claim 6, further comprising a presence of motion information field.

8. The data structure of claim 7, further comprising a mode information field.

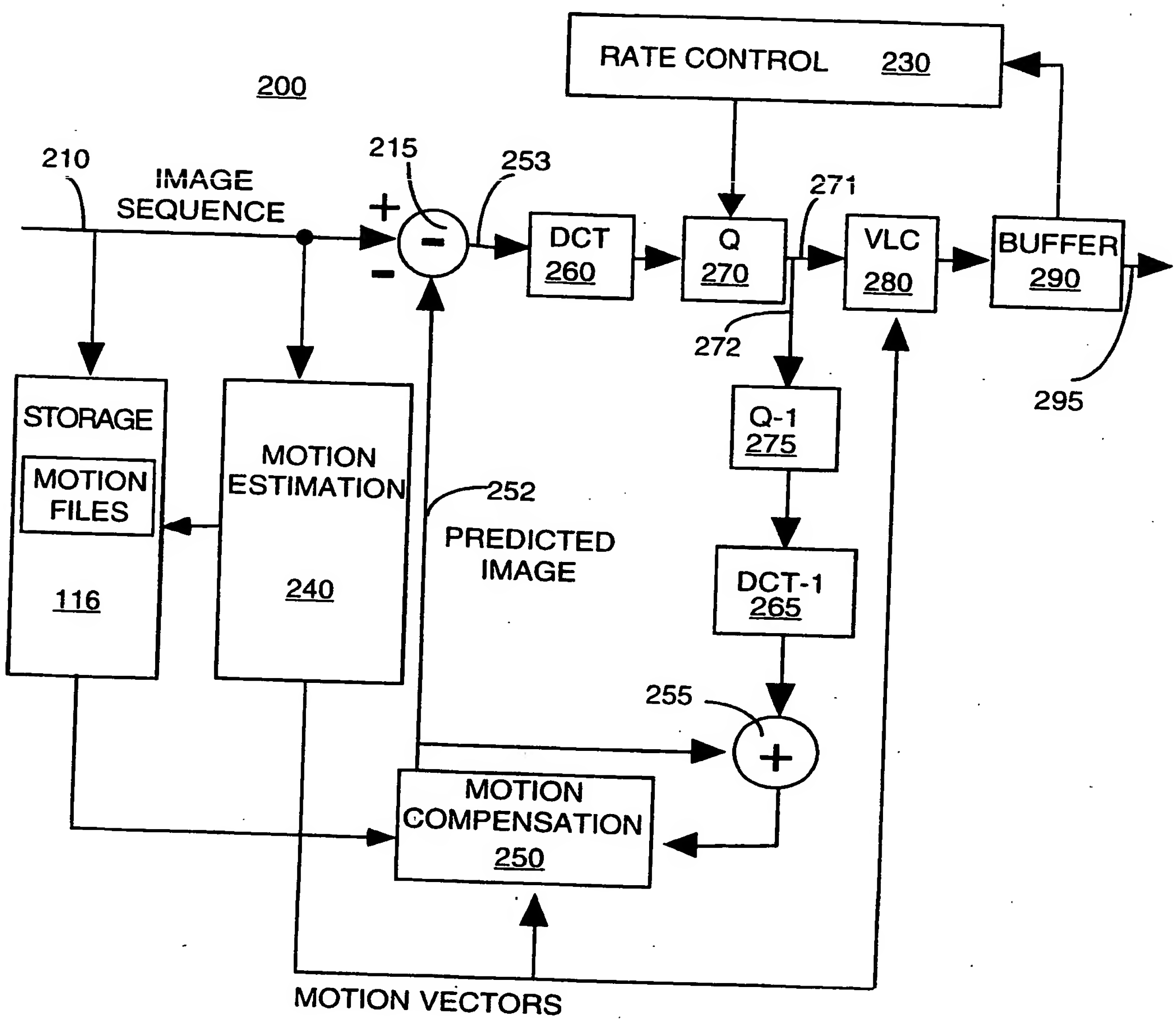
9. A server for dynamically controlling the frame rate of an image sequence, said server comprising:

a means for transferring the image sequence at a first frame rate;

a means for receiving a request for a change from said first frame rate to a second frame rate; and

wherein said transferring means transfers the image sequence at said second frame rate by retrieving stored information of said image sequence in accordance with said second frame rate.

10. The server of claim 9, wherein said stored information is a stored motion information of said image sequence encoded at said second frame rate.



200
RATE CONTROL 230
210
IMAGE SEQUENCE
215
253
271
+
-
DCT 260
Q 270
VLC 280
BUFFER 290
272
295
Q-1 275
STORAGE
MOTION FILES
116
MOTION ESTIMATION
240
252
PREDICTED IMAGE
DCT-1 265
255
+
MOTION COMPENSATION 250
MOTION VECTORS

FIG. 2

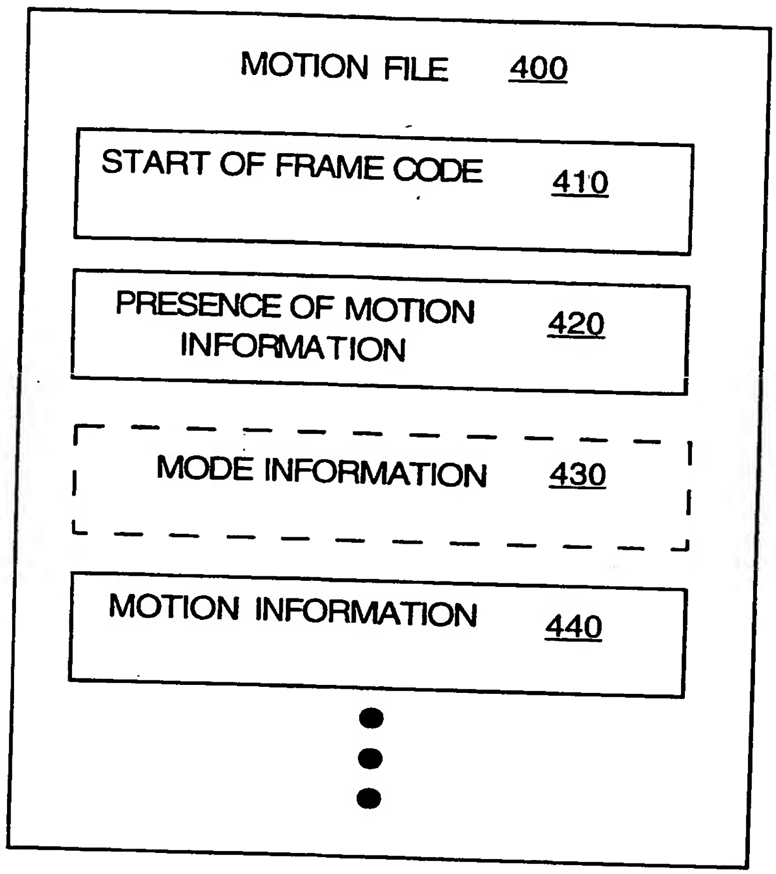

MOTION FILE 400
START OF FRAME CODE 410
PRESENCE OF MOTION INFORMATION 420
MODE INFORMATION 430
MOTION INFORMATION 440

FIG. 4

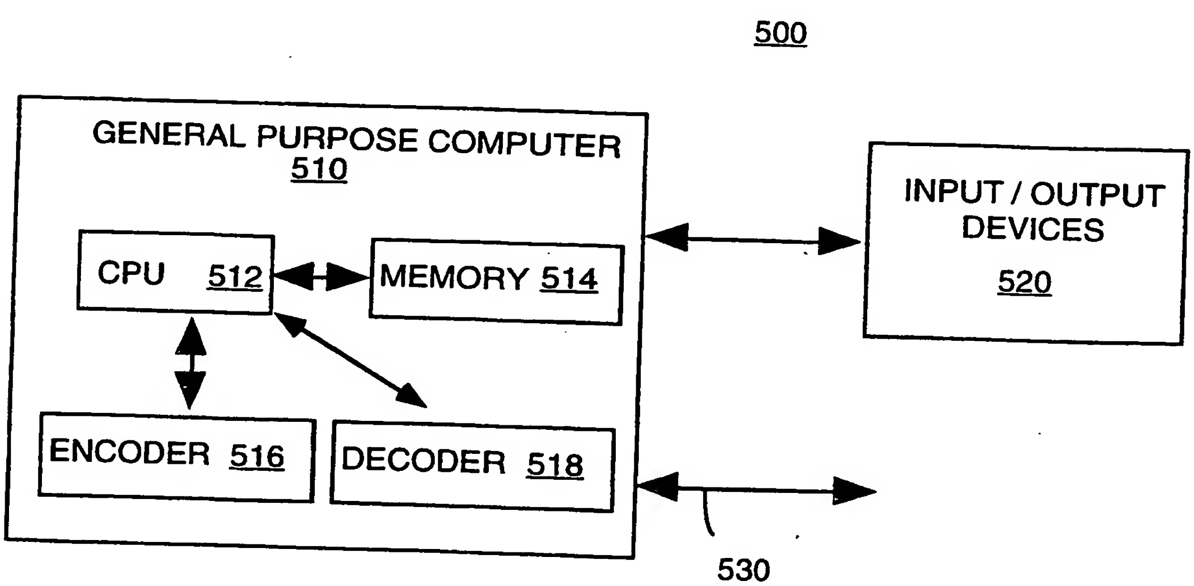

500
GENERAL PURPOSE COMPUTER 510
CPU 512
MEMORY 514
ENCODER 516
DECODER 518
INPUT / OUTPUT DEVICES 520
530

FIG. 5

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter nal Application No
PCT/US 99/14510

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0776130 A	28-05-1997	JP 9266548 A	07-10-1997
WO 9722201 A	19-06-1997	EP 0867003 A	30-09-1998

Form PCT/ISA/210 (patent family annex) (July 1992)

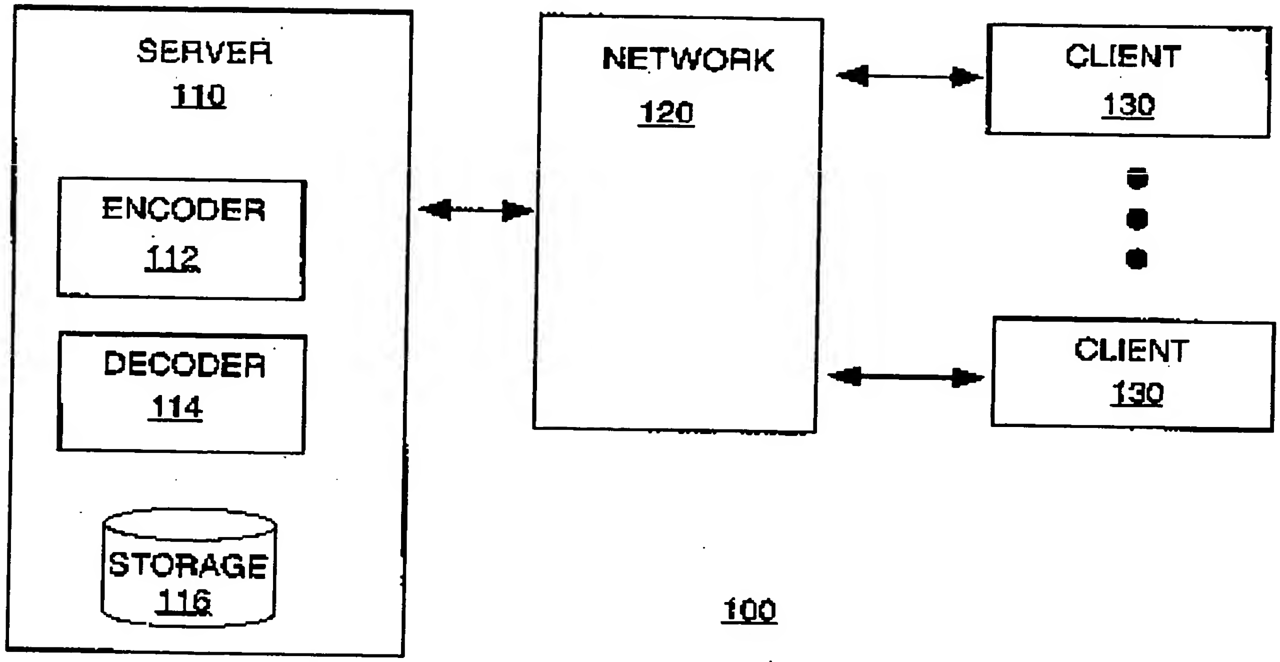

SERVER
110
ENCODER
112
DECODER
114
STORAGE
116
NETWORK
120
CLIENT
130
CLIENT
130
100

FIG. 1

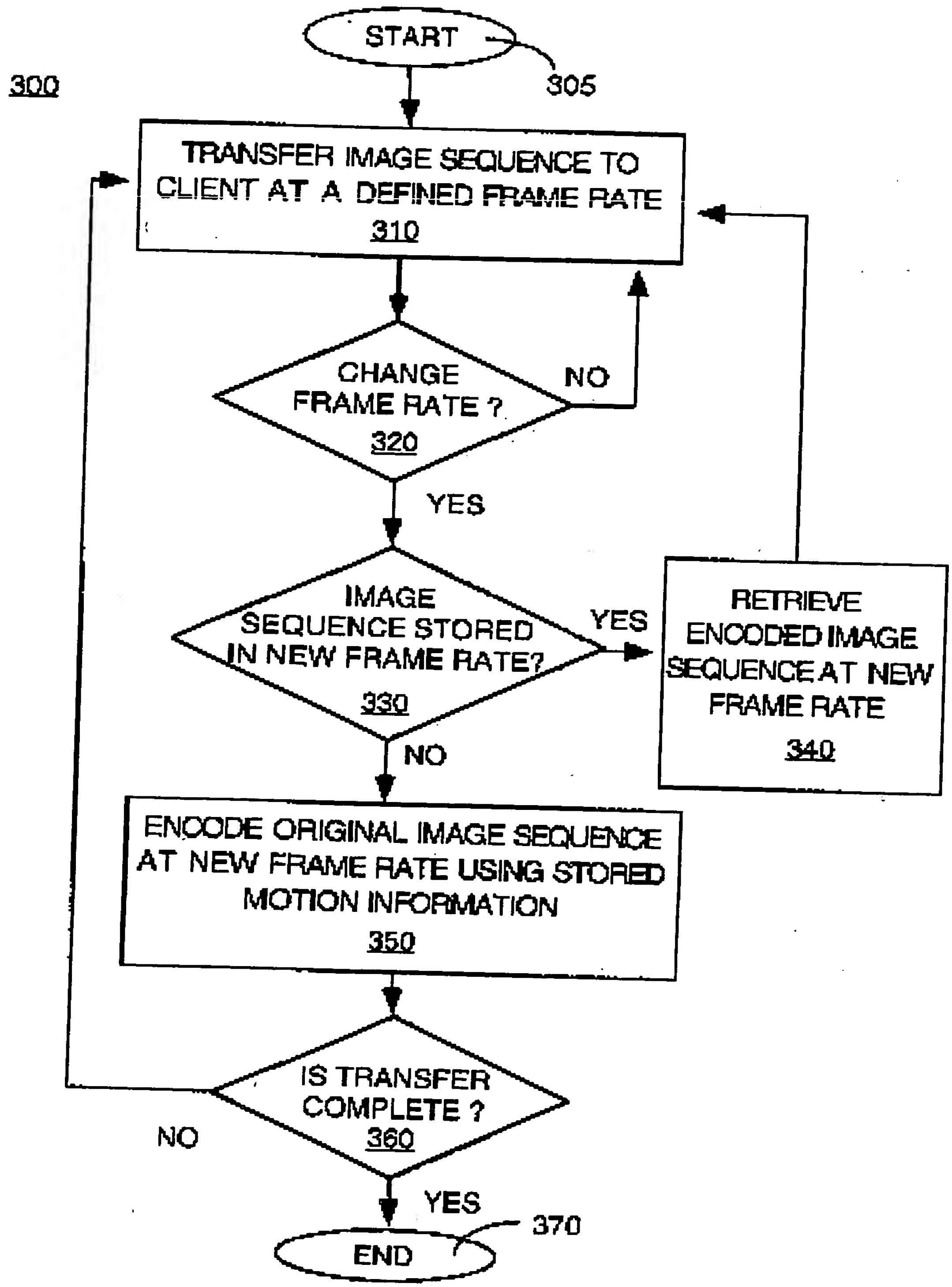

300
START
305
TRANSFER IMAGE SEQUENCE TO CLIENT AT A DEFINED FRAME RATE
310
CHANGE FRAME RATE ?
320
NO
YES
IMAGE SEQUENCE STORED IN NEW FRAME RATE?
330
YES
RETRIEVE ENCODED IMAGE SEQUENCE AT NEW FRAME RATE
340
NO
ENCODE ORIGINAL IMAGE SEQUENCE AT NEW FRAME RATE USING STORED MOTION INFORMATION
350
IS TRANSFER COMPLETE ?
360
NO
YES
370
END

FIG. 3